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Returns with wholesale-price-discount contract in a newsvendor problem

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ABSTRACT

We consider a newsvendor problem in a supply chain that consists of a manufacturer and a retailer. The manufacturer is the Stackelberg leader and the retailer is the follower. We examine how the manufacturer can contract a wholesale-price-only agreement with its retailer that maximizes its profit. We also propose a returns policy with a wholesale-price-discount scheme (returns-discount contract) that can achieve supply chain coordination. Using the wholesale price only contract as a benchmark, we show how the manufacturer sets a discounted wholesale price in a returns-discount contract that enhances both profits of the manufacturer and the retailer, as well as improves the supply chain efficiency.

1. Introduction

As the competition is intensified in today's market, many companies realize that the performance of their business highly depends on the degree of collaboration and coordination across the supply chain. The newsvendor problem is to find the optimal order quantity for a single period selling that maximizes the expected profit. Newsvendor-type products (such as USB flash drivers, fashion apparel, personal computers, etc.) are characterized as style or seasonal products (Mostard et al., 2005; Yao et al., 2005b). Their short life cycles result in little or no salvage value for the products that are left at the end of the selling season, which make supply chain collaboration and coordination particularly critical. A supply chain that consists of a manufacturer supplying a product to a retailer has been studied by many researchers (see, e.g., Lee and Rhee, 2010; Wang and Liu, 2007; Corbett and DeCroix, 2001). Structuring a contract between the manufacturer and the retailer to incentivize a decentralized supply chain to operate as an integrated or centralized supply chain has attracted much attention of both academics and practitioners. In this paper, we propose a returns-discount contract to coordinate the supply chain for the case where the manufacturer is the Stackelberg leader, and the retailer is a follower and a "newsvendor" facing demand uncertainty with an exogenous retail price. The retailer decides the order quantity, and the manufacturer decides the wholesale price considering the retailer's order quantity.

Many researchers have proved that a wholesale price only contract cannot coordinate a supply chain (see, e.g., Cachon, 2003; Bernstein and Federgruen, 2005; Lariviere and Porteus, 2001). As independent entities in the supply chain, both the manufacturer and the retailer seek to maximize their own profit, resulting in the well-known "double marginalization" (Spengler, 1950) problem. Double marginalization results in the optimal order quantity for the retailer being lower than the optimal order quantity in a coordinated supply chain because the wholesale price is set above the manufacturer's cost, leading to a lower margin for the retailer. Some kind of mechanism or incentive is required in order to coordinate the supply chain through an agreement between the manufacturer and the retailer; this will induce the retailer to increase the order quantity and thereby mitigate double marginalization. See Lariviere (1999), Taylor (2002), Cachon (2003), and Arshinder and Deshmukh (2008) for detailed discussion of diverse coordination contracts.

Cachon (2003) points out that "the contract designer may actually prefer to offer a simple contract." Many supply chains in practice still use the wholesale price only contract due to its simplicity. That is, the manufacturer sells his products with a posted wholesale price per unit. The wholesale price only contract is usually used as a benchmark when researchers evaluate other proposed contracts. Van Ryzin and Mahajan (2000) analyze the Vendor Managed Inventory (VMI) and the Retailer Managed Inventory (RMI) systems by using the wholesale price only contract. They show that, as the number of competing retailers increases, the efficiency of the supply chain increases.

For a general distribution of demand function, if the retailer is a "newsvendor" who should make the order quantity decision, the order quantity depends on the wholesale price that the manufacturer sets. Anupindi and Bassok (1999) consider a case that the manufacturer sets a wholesale price using an approximation of normal distribution. Lau and Lau (1999) examine the impact of the manufacturer's wholesale price on the performance of the supply chain based on the examination of numerical studies. Without considering shortage cost, Lariviere and Porteus (2001) show that a wholesale price only contract cannot achieve supply chain coordination in a

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newsvendor problem. They explore two considerations that may lead the manufacturer to choose a lower wholesale price: the retailer's participation in forecasting to gather more precise demand information for the supply chain, and leveraging the retailer's power. They show that the optimal wholesale price depends on the coefficient of variance and can be determined by finding out the manufacturer's optimal sales quantity. Differing from Lariviere and Porteus (2001), we analyze the optimal wholesale price by considering the retailer's action on order quantity into the manufacturer's profit function and present the condition for the *existence* and *uniqueness* of the optimal wholesale price. We also propose another reason why the manufacturer considers the wholesale-price discount by proving that, as the wholesale price increases and approaches its optimum, the manufacturer's profit is insensitive, while the retailer's profit is sensitive to the slight change in the wholesale price. This result suggests that the manufacturer wanting to promote the retailer's loyalty and retain a long-term relationship that can offer a wholesale-price-discount contract to encourage the retailer's ordering more products, consequently enhancing the retailer's profit at the expense of slightly lowering the manufacturer's profit.

The price-discount scheme has been discussed in the literature. Dada and Srikanth (1987) show that price discount can minimize the chain-wide costs and, therefore, can improve the efficiency of the supply chain. Weng (1995) considers a problem with price-sensitive demand. His model shows that wholesale-price discounts can increase the amount of demand and achieve a Pareto optimization. However, these papers do not analyze how the manufacturer sets its wholesale price and how this decision affects the retailer's profit and efficiency of the supply chain.

Researchers have proposed various contracts that can coordinate the supply chain; for example, quantity discount contracts (Shin and Benton, 2007; Li and Liu, 2006), revenue-sharing contracts (Cachon and Lariviere, 2005; Giannoccaro and Pontrandolfo, 2004, 2009), rebate policies (Arcelus et al., 2007; Taylor, 2002), and returns policies (Padmanabhan and Png, 1997; Emmons and Gilbert, 1998; Yao et al., 2005a, 2005b; Choi et al., 2004). An intriguing research stream in the field of the supply chain coordination is on combinatorial effects of the concurrent adoption of two coordination mechanisms; for example, consignment contract with revenue-sharing (Li et al., 2009; Wang et al., 2004), volume discount and franchise fees (Qin et al., 2007), sales rebate contract and Vendor-Managed Inventory (Wong et al., 2009), and revenue-sharing and advance booking discount programs (Bellantuono et al., 2009). Li et al. (2009) show that a consignment contract with revenue sharing can coordinate the supply chain with an upstream manufacturer and a downstream retailer. Qin et al. (2007) find that volume discounts are not sufficient to guarantee the maximization of the system profit. The coordination can be achieved by employing both volume discounts and franchise fees simultaneously. Wong et al. (2009) show that a sales rebate contract achieves coordination in a supply chain with a single supplier serving multiple retailers in a Vendor Managed Inventory (VMI) partnership. In this paper, we show that a returns policy with the wholesale-price discount can achieve supply chain coordination.

Li and Liu (2006) consider quantity discounts as a mechanism to achieve channel coordination when demand is probabilistic. Giannoccaro and Pontrandolfo (2004) analyze a revenue-sharing contract for the coordination of a three-stage supply chain. Cachon and Lariviere (2005) show that, under a revenue-sharing contract, the manufacturer will set a wholesale price below production cost if manufacturer and retailer agree to share the total revenue of the supply chain.

With a returns policy, manufacturers can encourage retailers to order more than the quantity obtained by optimizing the retailer's profit. Returns policies are widely used in many industries, especially for products with short life cycles such as books, CDs, holiday gifts, and computers. Pasternack (1985) first investigates methods of channel coordination through a returns policy for a seasonal product under the newsvendor framework. He shows that there exists a wholesale price and a buyback price that can achieve channel coordination, and that different wholesale prices and buyback prices result in different ways of splitting the entire chain's profit between the manufacturer and the retailer. However, his work does not identify when the retailer and/or the manufacturer can benefit from a returns policy.

Lau and Lau (1999) analyze a pricing and returns strategy for a manufacturer and show that a returns policy can be used by the manufacturer to increase profit instead of losing its profit share to the retailer. Their work does not include the issue of how the manufacturer sets the wholesale price to ensure a win–win for both the manufacturer and the retailer. Padmanabhan and Png (1997) examine the role of a returns policy in a competitive environment. They use a linear price-dependent demand to derive the optimal wholesale prices. They do not analyze the case of the retailer facing a general form of uncertain demand. Under the general form of demand with uncertainty, we propose the returns with-wholesale-price-discount (returns-discount) mechanism that can achieve the supply chain coordination. We analyze when such a returns-discount contract can be a win–win for both the manufacturer and the retailer. Using the case that the manufacturer offers a wholesale price only contract as a benchmark, we illustrate how a returns-discount contract can be implemented to enhance both profits of the manufacturer and the retailer.

The rest of the paper is organized as follows. We present models, existence condition of the optimal wholesale price, and a returns-discount contract that can coordinate the supply chain and be a win–win for both the manufacturer and the retailer in Section 2. Numerical examples to illustrate our results and insights are given in Section 3. Section 4 gives conclusions. Proofs are given in the Appendix.

2. The models

We consider a newsvendor problem in which the manufacturer is a Stackelberg leader selling a product to the retailer who is the follower in a supply chain. The product is a style or seasonal item with a short life cycle. We assume that the unsold product has no salvage value at the end of selling season. The retailer faces an uncertain demand $X=D+\xi$, where D is the expected demand and ξ is the demand uncertainty. To ensure that non-negative demand is possible, we assume that ξ is well defined in the range $[-A, \infty)$, where $A \leq D$. Define $f(\cdot)$ as the probability density function and $F(\cdot)$ as the cumulative distribution function of ξ. In addition, we assume that $F(\cdot)$ is invertible and is strictly increasing and that $f(\cdot)$ has a continuous derivative $f'(\cdot)$. The retail price (p) is given. Both the demand distribution and p are known to the manufacturer as well as to the retailer. The retailer must decide the order quantity (Q). The shortage cost is g per unit if demand cannot be met. We assume that the retailer has only one opportunity of replenishment in a selling period. The production cost is c per unit and the manufacturer must decide the wholesale price (w). We start with the discussion of the benchmark case i.e., the wholesale price only contract.

2.1. The wholesale price only contract

The manufacturer charges the retailer a wholesale price (w) per unit purchased, and the retailer sells the product at the retail price (p) to its customers. The retailer takes all risk of keeping any unsold stock. This simple transaction between the manufacturer and the retailer is referred to as a wholesale price only contract. The manufacturer, a Stackelberg leader, offers the terms of contract as a take-it-or-leave-it provision to its retailer. We simply assume